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## Understanding Project Based Production through Socio-technical Modularity

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### ABSTRACT

*This paper develops an approach for understanding Project Based Production. This form of production is characterized by unique deliverables, high complexity, high value, high risk, profound uncertainty and many stakeholders and is increasingly important the postmodern society. Common to the practices of PBP and other production practices is the goal of balancing the dilemma between creativity and productivity.*

*In response to industrialized production, the concept of modularity gained popularity for addressing this dilemma by exploring product, process and organization structures. However with the starting point in system theory and a strong bias towards industrial production, the predominant understanding of modularity faces difficulty in explaining practices of Project Based Production in both social – technical and dynamic – stable aspects.*

*Illustrated by a case the paper addresses this gap, by offering a reinterpretation of the modularity concept from a socio-technical perspective in general and Actor Network Theory (ANT) in particular. By formulating modularity from an ANT perspective covering social, material and process aspects, the modularity of a socio-technical practice can be understood as an entanglement of product, process, organizational and institutional modularity.*

*The paper concludes proposing central questions for the development of the concept of modularity for understanding, designing and managing of PBP.*

**Keywords:**

Project Based Production, Modularization, Actor Network Theory

## INTRODUCTION

An increasing share of the production in the postmodern society is realized through projects. This form of production, which might be termed Project Based Production (PBP), is characterized by high complexity, high value, many stakeholders and unique productions. A few classic examples of areas are construction projects (e.g. buildings, infrastructure and renovation), and offshore projects (e.g. oil and gas platforms, wind farms and shipbuilding). However PBP not only relates to physical products, but can also be found within the creative industries (e.g. movie productions, theatrical productions, festivals and concerts) and in the healthcare industry (e.g. patient operations).

Common to these cases is that in practice, they must balance the dilemma between creativity and productivity. Since March (1991) coined the dilemma of exploration and exploitation, successful management of this dilemma is seen as a foundation for growth, because creativity is important for creating value while productivity ensures an optimal utilization of resources.

In the practical handling of this dilemma, practices of PBP draw on different management philosophies from operation and project management. However, whereas traditional industrial production practices are characterized by stability, well defined user needs and a strong separation between development and production, PBP practices are often characterized by high complexity, uncertainty, emergence, unknown and changing customer needs and an entangled development and production.

In recent years the concept of modularity has been subject to growing attention among academics and practitioners as it is seen as a crucial strategy for handling complexity and risk in

postmodern production practices, enabling organizations to produce goods and services meeting individual customers' needs while still leveraging the benefits of similarity and standardization.

Modularity has gained particular popularity as a central concept for exploring different kinds of production-related structures, such as product structure, process structure, organizational structure and supply chain structure (Salvador 2007 and Campagnolo & Camuffo 2009).

In an extensive literature review of modularity in relation to management studies, Campagnolo & Camuffo (2009) identify a complex field of approaches offering different definitions, measures and applications of the modularity concept. Despite the fragmented nature of the field, they identify three units of analysis among modularization scholars – product, production system and organizational design modularity. Out of the 125 scholars reviewed, only 3 address all three levels. Consequently the relationship between modularity in product, production and organization design not sufficiently studied. They conclude that the development of an all-round framework that encompasses all the three levels is needed (p. 278).

Modularity has been subject to intense research and several scholars have tried to develop a general theory of modularity like Schilling (2000) based on systems theory. However Campagnolo & Camuffo (2009) find that most of the existing works is based on an assumption of technological determinism (p 279). Moreover Fixson (2006) argues that modularity “have been studied mostly in static situations, i.e., conditions are identified in which one type of modularity is superior to another, or in which commonality is superior to non-commonality while all other conditions are held constant. In reality, however, no system is really static. Products change, processes evolve, organizations adapt, and innovations appear, and all of these changes are accelerating.” (p.31)

The outset from system theory, including the technological determinism and stability, makes it hard to explain the dynamic contexts and socio-material entanglements of modularity.

Consequently, traditional modularization approaches have difficulty explaining the modularity of Project Based Production practices covering cultural differences, learning processes, socio-material organization and institutional influences.

In parallel with the development of the concept of modularity and Actor Network Theory has witnessed an increasing popularity in theorizing the emergent and unpredictable nature of project work (Sage *et al.* 2011). In contrast to most research on Modularity, ANT is part of a wider “practice turn” within management and organizational studies who in theorizing on projects places emphasis on understanding management through the unpredictable, embodied, and materially mediated, lifeworlds, of practitioners themselves, rather than through “best practice” ideals, abstractions and rationalist models of human behavior (Nicolini *et al.* 2003, Schatzki *et al.* 2001).

In relation to Project Based Production ANT has been applied for understanding diverse projects as; building (Sage *et al.* 2011, Tryggestad *et al.*, 2010; Harty, 2005, 2008; Suchman, 2000; Yaneva, 2009), transport (Ivory and Alderman, 2005; Latour, 1996), information system (Tatnall and Gilding 1999) and aerospace (Law, 2002). While none of these addresses the concept of modularity the general impression is that ANT is a promising strategy for studying project work thus is Sage *et al.* (2011) concluding that ANT might “contribute to the further understanding of the dynamic, interdependent and emergent stabilizations and negotiations that constitute complex projects.” (pp. 288)

## **AMBITION**

The ambition of the paper is to explore the possibilities for understanding modularity from a socio-technical perspective in general and Actor Network Theory in particular. More specifically the intention is to develop:

*an approach for analyzing the modularity of Project Based Productions practices covering both social – technical and dynamic – stable aspects.*

Thus the objective is to formulate modularity in a new perspective which might challenge the existing boundaries and open up new avenues of research and practice.

## **METHODOLOGY**

The strategy for achieving this is a reinterpretation of the modularity concept from Actor Network Theory combined with an illustrative case on PBP. The empirical material for this case analysis stems from an ethnographic study, with primary focus on design activities (Thuesen 2006). During an 18-month period, the author were present in the project, participating on a daily basis in the ‘main’ design activities, which covered all design meetings, workshops, and some internal and external meetings. In addition to participant observation, project members were interviewed. An extensive part of the material (i.e. meetings and interviews) has been taped, resulting in more than 90 hours of recordings. Furthermore, the formal documents created by the actors have been made available, such as contracts, resumes, drawings and so on.

The rich field material was originally gathered and analyzed using practice-based theory including Actor Network Theory (Thuesen 2005). This analysis involved selecting special topics and studying knowledge processes around them. In this article the case is used as an example of PBP practices for the study of the concept of socio-technical modularity. Since it would be an impossible exercise to present all this material in the format of an article, the focus is on one illustrative picture. The picture represents a thick description (Geertz 1973) of a PBP practice making it possible to illustrate the approach for understanding socio-technical modularity.

It is a limitation in the present work that modularity is introduced as an ex-post analytical category. The original material, however, is rich and multifaceted, and therefore provides the opportunity for further qualitative analysis than that which practice-based theory originally provided. Moreover, an ethnographic study introduces close encounters between the observer and the actors in the field. Two limitations were prevalent here: one is that the study's point of departure was in the participating contractor; another is that the observer was a trained engineer and thus might exercise occupational bias (Loosemore and Tan 2000). Some practices were employed during the 18 months to avoid this, which included a visit to the architect's workshop as part of the study. Also, the author's occupational bias may have been of a more managerial nature rather than leaning toward the construction engineering actors participating in the project.

### **AN ILLUSTRATIVE CASE ON PROJECT BASED PRODUCTION**

The case represents a typical postmodern construction practice as described in the following table:

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Insert Table 1 about here

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The project studied aimed to develop the school system of a municipality and included constructing a new school and refurbishing four existing schools. Due to EU regulations the project was organized as a design-build contract with a target sum. Following the tender and a joint kick-off workshop, a partnering agreement was signed between the client, the selected design-build contractor, the architect and the consulting engineer. Thereby the project was organized based on the institutionalized division of labour between professions such as architects, engineers, contractors and crafts. The professions are rooted in educational background and sustained by apprenticeship learning processes, ensuring a formal separation between design and production and the management of the craft practices.

The project was a typical ‘one of a kind’ construction, where the schools were each designed and refurbished to meet the specific needs of the local users. This process was characterized by constantly changing user preferences and a great deal of iterations and rework. The design was carried out by the architects and engineers but due to the constant changes in the project material, many design decisions were made onsite by the craftsmen.

The schools were designed in a Scandinavian design tradition using large window areas in order for daylight to penetrate the building. Unlike mainstream construction practices, the primary building materials were glue laminated timber and wood panels for the façade and roof with limited use of concrete elements for ensuring the stability of the building. Due to the heavy use of timber materials, the predominant craft on the site during the construction was carpentry.

The management of the project and the coordination and supervision of the different professions was established through classic project management practices using planning tools such as MS Project, successive calculations, stakeholder analysis, project documents management systems (extranets) and workshops.

We will now turn to a specific instance in the project (the picture) where two carpenters install a window under the supervision of a construction manager (red helmet).

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 Insert Figure 1 about here  
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In the picture we can identify how the practice consists of a variety of tangible items including the window, the people (i.e. carpenters and construction manager), tools (i.e. suction cups, drill, spirit level and hammer) and drawings. However within the picture, we cannot see the (intangible) dimension of their practice. While they install the window, they also use language, their meanings, attitudes and experiences - elements we cannot immediately identify in the picture. The tangible and intangible dimensions refer to the practice material and discursive elements.

The context within which the practice unfolds can also be divided into a tangible and an intangible dimension. We can talk about a physical and an abstract space. The physical space is the physical environment such as the beam of glue laminated timber that the window must be attached to, as well as the construction site. The abstract space represents how practices are

influenced by dominant discourses, e.g. how the construction manager would rush the carpenters, so they could meet the scheduled deadline.

This case (picture) will act as an exemplary case for developing an approach for understanding the socio-technical modularity of PBP practices. But first the concept of modularity is introduced.

## **THE CONCEPT OF MODULARITY**

According to Schilling (2000), modularity is a general systems concept, typically defined as a continuum describing the degree to which a system's components may be separated and recombined. Usually it refers to both the tightness of coupling between components, and the degree to which the "rules" of the system architecture enable (or prohibit) the mixing and matching of components (p. 312). Given the open-ended nature of the concept, it is used in a variety of academic and practical fields like biology, nature, ecology, mathematics, cognitive science, industrial design, manufacturing, programming and art and architecture.

Given the broad acceptances of the concept, Campagnolo & Camuffo (2009) argue that every system is modular to some extent. This gives rise to different ways of understanding and describing modularity. According to Fixson (2003), the modularity of a system can be described by either focusing on the elements or relations as illustrated in the following figures.

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*Insert Figure 2 about here*

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In Campagnolo & Camuffo's (2009) review of the concept of modularity, they identify three streams of literature clustered around three different units of analysis: (a) product design modularity, (b) production system modularity; and (c) organizational design modularity (p. 260). In the following, these categories are referred to as product, process and organizational modularity.

### **Product modularity (product design modularity)**

Among the different units of analysis Campagnolo & Camuffo (2009) find that the product design modularity has received the greatest attention from scholars and practitioners probably because it's primarily technically, material and normative orientation.

With the outset in platforms thinking, Meyer *et al.* (1997) describe the architecture of a product as being the combination of subsystems and interfaces. They argue that every product is modular and that the goal is to make that architecture common across many variants. Ulrich (1995) believes that product modularity is the scheme by which the functions of the product are mapped towards the physical components, thus defining the product architecture as the arrangement of functional elements, the mapping from functional elements to physical components and the specification of interfaces between these.

The use of product architecture with well-defined modules has in several cases proved to contribute to significant increases in industrial productivity, since implementation of product architecture with well-defined interfaces maintained over many years, makes it possible to develop production processes that are more productive. One reason is that the well-defined

interfaces make it considerably simpler to coordinate the individual sub-processes that are typically carried out by different organizational groups.

### **Process modularity (production system modularity)**

Building on the insights from platform thinking and product architectures Baldwin and Clark (1997) defines modularity as a strategy for organizing products and processes efficiently (p. 86). According to Campagnolo & Camuffo's (2009) this type of modularity "within and among organizations mirrors the degree of product modularity, with the main consequence that independent companies (e.g. suppliers) may develop, produce and deliver self-contained modules consistent with the scope and depth of their core competences." (p. 269)

Thereby modularity not only is a characteristic of a product but also the processes / task / activities for producing it. One of the consequences of focusing on modular processes is that the end product might be intangible like a service or experience (Pine and Gilmore 1999).

### **Organizational modularity (organizational design modularity)**

Organizational modularity might be referred to as the way organizations are structured.

Since the seminal work by Daft and Levin (1993) where they first coin the concept of the modular organization, several scholars have devoted much effort to develop new organizational paradigms "characterized by flatter hierarchies, decentralized decision-making, greater capacity for tolerance of ambiguity, permeable internal and external boundaries, empowerment of employees, capacity renewal, self-organizing units, and self-integrating co-ordination mechanisms" (Campagnolo & Camuffo 2009, p 274).

A strand of these scholars are particularly interested in the relation between product and organizational modularity identifying the following relation: “[I]ntegral products should be developed by integral organizations (tightly connected organizational units to maximize ease of communication and minimize the risk of opportunism). Modular products should be developed by autonomous, loosely coupled, easily reconfigurable organizations. Indeed, the adoption of standards reduces the level of asset specificity (Argyres 1999; Cainarca *et al.* 1993) and, in turn, the need to exercise managerial authority. Product modularity also reduces the need for communication due to information hiding, whereby knowledge about the ‘interior’ of each module does not need to be shared.” (Campagnolo & Camuffo 2009, p 274).

Despite the growing interest in the concept of modularity, Campagnolo & Camuffo (2009) find no rigorous studies capable of linking the different perspectives (p. 277). The differences and similarities of existing approaches to modularization set requirements for bridging product, process and organizational modularity. Thus a reinterpretation of the concept of modularity should be able to understand a system with physical and material artifacts and social actors. Combined with temporal and dynamic characteristics of Project Based Productions practices, the reinterpretation must furthermore be able to handle stability and dynamism. This is basically what Actor Network Theory (ANT) tries to do.

## **THEORY OF ACTOR NETWORKS**

How can we describe the modularity of a socio-technical practice<sup>1</sup>, when it in one moment appears as a closed box, but at other times seems to consist of a jumble of elements and relationships? This is in its simplicity and in all its complexity, what ANT is concerned with. ANT is a theory of technology, science, social actors, society, nature and power, all analyzed with the same conceptual framework (Callon 1986a; Law *et al.* 1992; Latour 2005). Although ANT is not one unified theory, there are some key concepts such as network, actors and translations - concepts that spread far beyond the ANT's various research positions.

Actor Network Theory enables us, with the fundamental notions of “Actor and Network”, to understand how important components (actors) of a socio-technical practices such as carpenters, drawings, plans, previous buildings, users, masters, apprentice, project managers, material and resources are tied together (networked) and produces action (translation).

Unlike other theories about modularity, ANT is not a normative theory but an approach for understanding a socio-technical practice without subscribing predefined analytical categories such as organizational, product or process modularity any importance. But these categories might arise through analysis of the central concepts (actors, networks and translation).

## **Network**

Compared to the common understanding of modularity, ANT operates with a different topology - a network metaphor similar to the relational position that Fixson (2003) identifies. As

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<sup>1</sup> The concept of social-technical practice is here used as a metaphor for the empirical world covering both human and material elements.

illustrated in the following figure, ANT is based on a relational understanding of networks consisting of tangible and intangible, human and non-human actors - which are heterogeneous.

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*Insert Figure 3 about here*  
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ANT's assertion is that actors do not exist in virtue of themselves - but only are defined by their relationships to other actors in the network. According to Jensen (2004, p. 5), the network concept in ANT is very open. Thus are there no prior assumptions that the network has a special stability. Both a craft practice and a house can be considered as a network. There are no assumptions about size: both the microscopic to the universal can be included. Finally there are no assumptions that the network simply consists of one type of relationship (e.g. interpersonal). Rather, ANT analysis typically employs heterogeneous networks, i.e. a network that consists of many different types of relationships. Thereby ANT differentiates itself from Social Network Theory - which only operates with human actors and consequently focuses on interpersonal relations. There are no restrictions onto which socio-technical practices ANT might be applied. This is illustrated in John Law's comprehensive list of ANT studies<sup>2</sup>.

## **Actor**

The second fundamental concept in ANT is the actor concept that is included in the network. Thereby it also has a focus on the elements of a system like the first strategy Fixson (2003) identifies. However unlike existing theories on modularity, ANT operates with a fundamental

<sup>2</sup> [www.lancs.ac.uk/fass/centres/css/ant/antres.htm](http://www.lancs.ac.uk/fass/centres/css/ant/antres.htm)



principle of symmetry, where human and non-human actors are treated equally (Latour 1996, Law & Callon 1992). What is in focus is whether they "make" a difference by being either the subject or object of the activity.

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*Insert Figure 4 about here*

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An actor is attributed to the action going on in the network and can literally be anything as illustrated in the figure above. The people (carpenters, construction manager), the materials (windows, beam of glue laminated timber), the tools (suction cups, drill, spirit level, hammer), drawings are all example of actors, but also the building law and a weather phenomenon affecting the process can all be seen as actors. This open definition of the actor concept gives rise to confusion, since most other theories only use the actor concept in relation to human individuals. Thus this principle often generates an unproductive discussion among academics whether non-human actors have agency or not. The way around such discussions is to address the issue empirically, rather than ontologically. According to Suchman (2000), the strategy about treating human and non-humans actors equally is not the same as that they are symmetric. Thus people and artifacts do not relate to each other the same way but they are mutually defining each other through the network of relationships.

But if actors are not defined in virtue of themselves but by virtue of the act, how are actors then different from the network? According to ANT, there is no fundamental difference between actors and networks. Actors are networks that from a given perspective have developed stability

and thus appear as a "black box". These defined units respond predictably to specific inputs while the internal processes are invisible to the observer.

It is exactly the concept of the black box which is connected to the concept of modularity. Modules represent groups of actors which have been stabilized over time. In this way modularity can be interpreted as black boxes of actors. This is particular the case of product and organizational modularity where they respectively can be interpreted as a stable collection of non-human actors and human actors as illustrated in the following figure. Here the red boxes represent the product modularity of the windows while the blue boxes represent the organizational modularity of the carpenters and construction managers.

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*Insert Figure 5 about here*  
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ANT however doesn't only accept black boxes of either human or non-human actors. Thus Latour (1993) uses the term "hybrid" to illustrate that these can consist of both human and non-human elements.

As an example, a construction organization might be interpreted as a black box from an outsider, serving his or her needs. But from an actor inside e.g. an employee the organizational module might appear as a network of partially coherent actors and connections consisting of both human actors such as masters and apprentices and non-humans actors like tools, materials and physical environment.

The point of ANT's actor concept is that there is never any center where action originates from. Actions are achieved by arrangements in the network in such a way that one actor in the network acts on behalf of others. How long an actor can maintain their effect is an empirical question.

Callon (1992) establishes a special type of actor called "Intermediaries", which circulate between different actors and thus bind the network together. Intermediaries are therefore actors which mediate. They are both a cause and an effect of processes in the network. Gherardi & Nicolini (2000) explains it like this.

"They are both the 'visible' result of the assembling of heterogeneous elements by a network elsewhere in time and space, and the active effort of that network to produce some distant effect."  
(p. 335)

## **Translation**

But how are processes then understood in the actor network? The early ANT tradition analyses the dynamic element by the concept of translation, which covers how an actor obtains power by allying themselves with others (Callon 1986a)<sup>3</sup>.

"Translation is the mechanism by which the social and natural worlds progressively take form. The result is a situation in which certain entities control others. Understanding what sociologists generally call power relationships means describing the way in which actors are defined,

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<sup>3</sup> As mentioned previously, ANT is not "one" theory. Consequently there are differences between what is emphasized in ANT analysis. Thus the early ANT traditions are known as "the sociology of translation" interested in the concept of translation while later perspectives such as "the performative turn" focus on the performativity rather than translation (Jensen 2004).

associated and simultaneously obliged to remain faithful to their alliances.” (Callon 1986a, p. 224).

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*Insert Figure 6 about here*  
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Basically, translation processes links actors: A master represents his apprentice and a drawing describes the design principle of the school developed by the architect. In these cases, the actors are powerful because they are enrolled in a chain of prior actors. Prior to the apprentice change in practice, it has been approved by the master. And the drawing represents the result of talks among other architects. So when the master and the drawing can come up with a fairly stable credibility, it is by virtue of a long chain of previous translations (processes).

A classic ANT strategy is to follow the translations in the actor network. How is action produced and organized? The creativity in ANT therefore lies in the description of how the actor-network built up and stabilizes through translations in space and time.

Returning to the concept of modularity, the concept of translation enables us to explain and understand process-oriented modularity. While the translations cover all actions in an actor network, it is the premise for understanding process modularity. However given the stable characteristic modularity, not all translation can be interpreted as process modules. Process modularity might be interpreted as translations processes with a high degree of repetition among certain actors.

## **Critique**

According to Jensen (2004), one of the areas where ANT has been criticized is that the network metaphor has a tendency to get out of hand while at the same time has a tendency to paint socio-technical practices as very stable. Several researchers have tried to address this weakness. Mol & Law (1994) – some of the initiators for the development of ANT in a "performative" turn – suggest that one can handle this criticism by working with multiple topological metaphors. Networking is one way of tabulating socio-material relationships. Another relevant metaphor are “regions” that are known from traditional sociology, like Habermass’s concept of lifeworlds and Communities of Practice (e.g. Wenger 1998). Lastly the third metaphor "floating" paints loosely coupled actors without a clear center and which are constantly in motion.

## **DISCUSSION**

In the following, we will discuss the consequences of the socio-technical interpretation of the concept modularity and its relevance for understanding PBP. What are the consequences? What kind of insight does the new perspective give us? Which new strategies can we subsequently pursue?

### **The modularity is a matter of perspective**

As Campagnolo & Camuffo (2009) note, modularity is a characteristic of a system but also a matter of perspective. What from one perspective appears as a stable module might from another

appear as a subsystem of modules, elements and actions. These differences might stem from different professional backgrounds and different approaches for understanding modularity. From a future user of the schools, the construction organization might appear as a stable but rather chaotic entity but for a craftsman or project manager, it is a dynamic but yet ordered power struggle between different crafts, apprentice, project managers and materials.

Most strands of theories on modularity seem to have a rigid separation between social and material actors and presuppose certain types of analytical categories like organizational, supply-chain, process and product modularity. By focusing on actors, networks and translations, ANT rejects preexisting analytical categories. What characterizes the modularity of a socio-technical practice is in that sense an empirical rather than a theoretical question. Thereby new types of modularity might evolve from an empirical analysis like institutional modularity, tool modularity and modularity of practices. Revisiting the illustrative case, the straight-forward interpretation of the modularity would be that the carpenters and construction manager represent the organizational modules. A more honest interpretation would see the professions as institutionalized practices - a socio-material configuration of persons and artifacts. For instance, the carpenter's practice of installing the windows is based on rules of thumb, drawings, information about material, and so on. But it is also enabled by deep understanding of the physical possibilities and limitations in relation to the windows rooted in past experiences from other building projects. Since such an understanding is developed through generations, the modularity is also historical. Finally the practice is influenced by regulations like safety issues, building codes, and tendering systems adding an institutional dimension to the modularity.

It is this sensitivity towards the empirical domain that makes it possible to investigate the modularity of different types of PBP practices, without subscribing any existing analytical

categories any importance like product, process and organizational modularity. However, it is possible to develop a “pragmatic”<sup>4</sup> compatibility with classical modularization techniques like Product Variant Master (Hvam *et al.* 2008) and Modular Function Deployment (Ericsson and Erixon 1999). The point of connection is that an object in PVM or MFD can be viewed as an actor in ANT. Thereby it might be possible to benefit from the normativity of classical modularization techniques while at the same time benefitting from ANT's flexibility and dynamic focus.

### **Modularity in the making**

Basically the concept of modularity is a concept of stability but the dynamic ontology which Actor Network Theory is based upon enables us to understand the dynamic processes of the modularity of PBP practices.

ANT describes a world of networks, which constantly stabilize and destabilize. The translations in the actor net generate a socio-technical order but this order is sometimes fragile: The project manager is denounced by his craftsmen, and a roof structure collapses. Networking therefore implies a constant struggle to enroll and discipline the actors. Every time an actor is at the end of a translation process and thereby increases their strength, there is a kind of deflection, exploitation or abuse that makes the winning position fragile.

The consequence is that the modularity of a practice is always in the making. The modularity is just as much the result as well as premise for action. It is both the means and the end. This

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<sup>4</sup> I here use “pragmatic” in order to denote the underlying theoretical incompatibilities.

characteristic enables us to understand socio-material learning processes of modularity, exemplified in practices based theory (e.g. Wenger 1998 and Gherardi & Nicolini 2000).

Through socio-material learning theories, it is possible to develop an understanding of how the modularity is developed and reproduced, so let's revisit the case.

The building project is realized by developing and organizing various product, process and organizational modules. The interface between the different product modules, like the windows and concrete floor, is mirrored in the modularity of the professions. Thus the carpenters take care of the woodwork including the windows, while the concrete workers are responsible for the foundation and the placement of the concrete panels. This organization of the modularity is partly institutionalized by the professions, educational system and interest organizations partly locally designed and negotiated within the project. The carpenters practice is designed in the project by drawings and descriptions made by the architects and engineers and plans by the construction management. These "rules" for e.g. the placement of the glue laminated timber and the windows, sets the context for local negotiations among the carpenters of actual ways of carrying out the installation of the windows taking past experiences and personal motivation into account. Within the boundaries set by the institutional forces, the designers and managers of the project the carpenters might improvise and develop their own practice. As long as they improvise within the boundaries of their module/profession, the modularity of the project is reproduced. In this way, modularity goes hand in hand with repetition and renewal.

The design enables a somewhat repetitive process for installing the windows in school. However due to the unique design of the school the repetition only occurs within the project making it more difficult to develop effective learning processes across projects.



But it is not only the incremental changes that ANT and social-material learning theories allow us to understand. Through its focus on actors, networks and translations, ANT might help us explain how a tsunami might cause a nuclear meltdown and radically changing the modularity of future nuclear power solution. Thereby ANT can also help us to understand radical and eruptive innovations (Callon 1986 a and b).

### **Analyzing the modularity of a Project Based Production practice**

The usual strategy in ANT is to follow how action is produced in the actor net through translations processes. Although this strategy is fruitful for an in-depth understanding of the modularity of a socio-technical practice, it is also a challenging process.

A shortcut which might ease the analysis is by looking for elements of stability, standardization and repetition. Some guiding questions for analyzing the modularity of a PBP practice can be:

- What is produced/delivered (product/service/experience)
- How is it produced/delivered (process/practice/tool)
- Who is producing/delivering it (organization/practice/institutional)

The interesting question is not whether a PBP practice is modular, but what characterizes the modularity of the practice. Since every system is modular to some extent, it is interesting to start analyzing the modularity of different PBP practices in order to discover differences and similarities. Thus it could be interesting to identify the modularity of other construction projects but also for offshore projects and creative projects.

## **Managing modularity**

Given this insight in modularity, it is tempting to ask the question: “How can the socio-technical modularity of PBP be designed and managed?”

Since ANT is not a normative strategy, it doesn’t directly address practical managerial issues. As has been shown, ANT is able to understand modularity but it is not concerned whether it is good or bad.

Despite the lack of normativity in ANT, it might inform better managerial actions by developing a more robust understanding the modularity of a production practices. Especially combined with existing modularization tools like MFD and PVM, ANT might create more accurate and productive managerial practices.

The modularity of a PBP practice might be seen as a puzzle where the pieces fit more or less together. If the pieces fit well together, the practice will be characterized by order, efficiency and high reliability, but if the pieces do not match resource are needed to negotiate and align the interfaces resulting in high complexity, inefficiency and uncertainty. Consequently the traditional managerial practices strive for developing systems with a well-defined modularity. On the other hand it is important to notice that a poor modularity introduces uncertainties which offer potential elements for creativity and innovation.

Under the umbrella “managing in an age of modularity”, Baldwin and Clark (1997) state that modularity is an attribute of a complex system and advocate for designing structures based on Minimizing interdependence between modules and Maximizing interdependence within them,

making it possible to be mixed and matched in order to obtain new configurations without loss of the system's functionality or performance.

Since Adam Smith's "The Wealth of Nations", one of the premises for achieving a high productivity has been to establish learning curves through repetition of similar processes. As the key characteristics of a module, standardization and stability modules are central for pursuing productivity.

These learning curves might be achieved within the modules through the socio-material learning processes accumulating knowledge in communities of practices passing knowledge on from master to apprentice. But this learning also sustains a certain conservatism as the masters have the power to define whether a solution is good or bad, thereby inhibiting the adoption of new ideas.

By letting each module communicate and interact with the others via standardized interfaces that allow decoupling of modules decoupling, the interfaces both enables repetition and development. Thereby modularity is a potential strategy for handling the dilemma of creativity and productivity within PBP.

The handling of this dilemma is central in the development of strategies for sustaining competitiveness in a globalized economy. In this sense, the guiding questions for understanding the modularity of a PBP practice need to include aspects of the market. Central managerial questions could be:

- Who are your users?
- Where are the needs of users/customers identical and diverse?
- How do you handle their differences and leverage their similarities?

### **Directions for further studies**

As most existing modularization techniques have been developed from a mass production context characterized by stability, as exemplified in the methods PVM and MFD, they might have a limited field of application in relation to PBP practices as seen in the construction industry, which is characterized by strong institutional forces, volatile markets and hyper complex production practices. In line with the saying “For a hammer everything is a nail”, there is a danger that we might use developed tools inappropriately. Thus it is important to have a reflexive approach, being sensitive to the empirical field in the development/modification of tools and practices to study, design and manage modularity. This opens up a research agenda regarding:

- Clarification of the concept of Modularity (theoretical and practical)
- Conducting empirical analysis of the modularity of different socio-technical practices
- Development of tools and practices for studying, designing and managing modularity.

### **CONCLUSION**

This article offers a new interpretation of the concept of modularity enabling a more honest understanding of Project Based Production. Based on the dynamic, socio-material perspective within Actor Network Theory, the approach enables us to:

- identify different types of modularity based on a empirical sensitivity covering modularity is relation to organization, products, process, tools, institutional, and practices
- link the different types of modularities

- grasp the dynamic nature of socio-technical practices and thereby understand modularity as a process rather than something stable
- understand the socio-material learning processes of a modular practice making it possible to understand how the modularity is reproduced
- handle the dilemma between creativity and productivity.

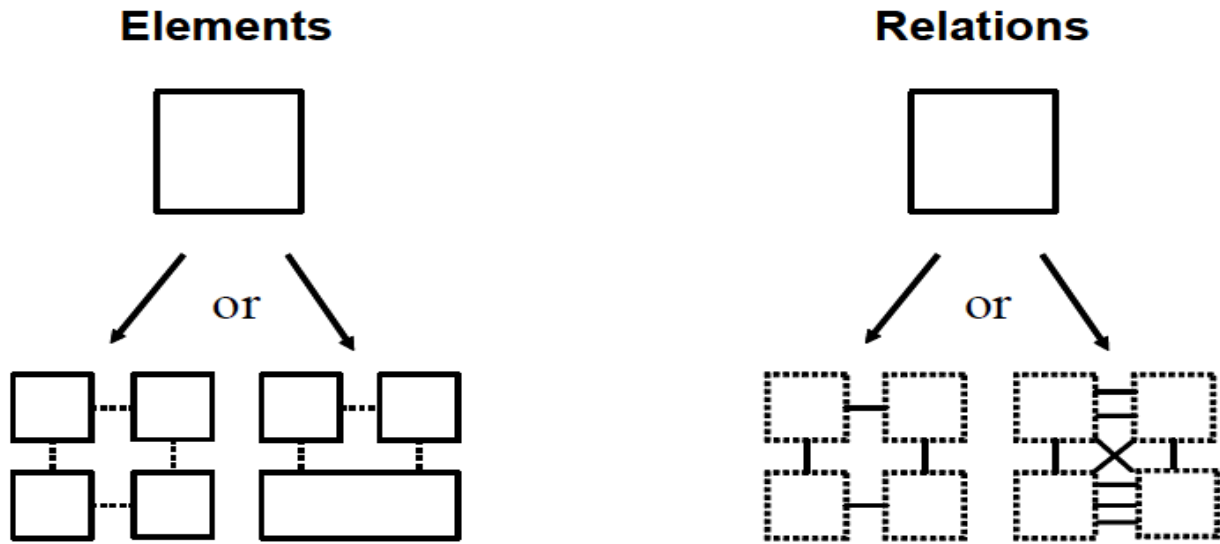
**FIGURES****FIGURE 1**

**Picture of Project based production practices**

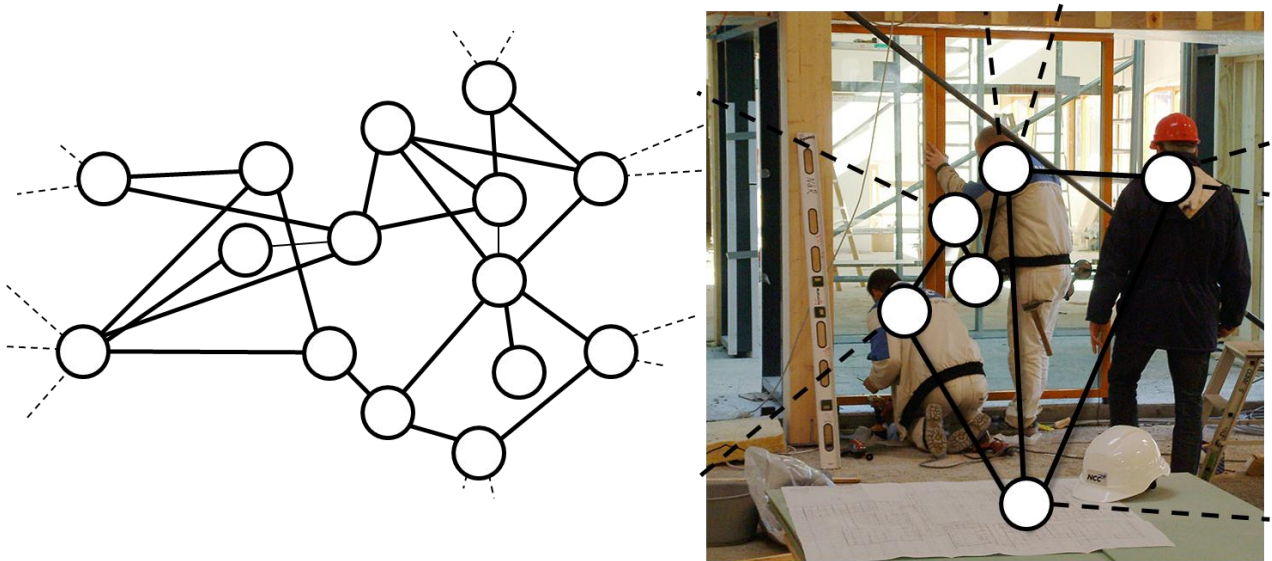


**FIGURE 2**

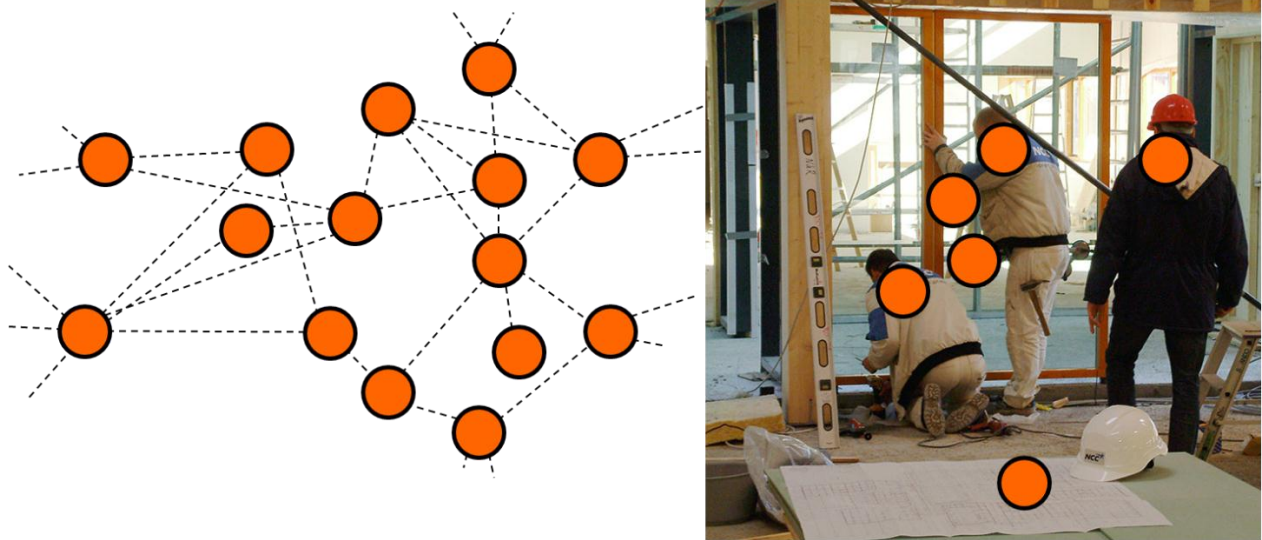
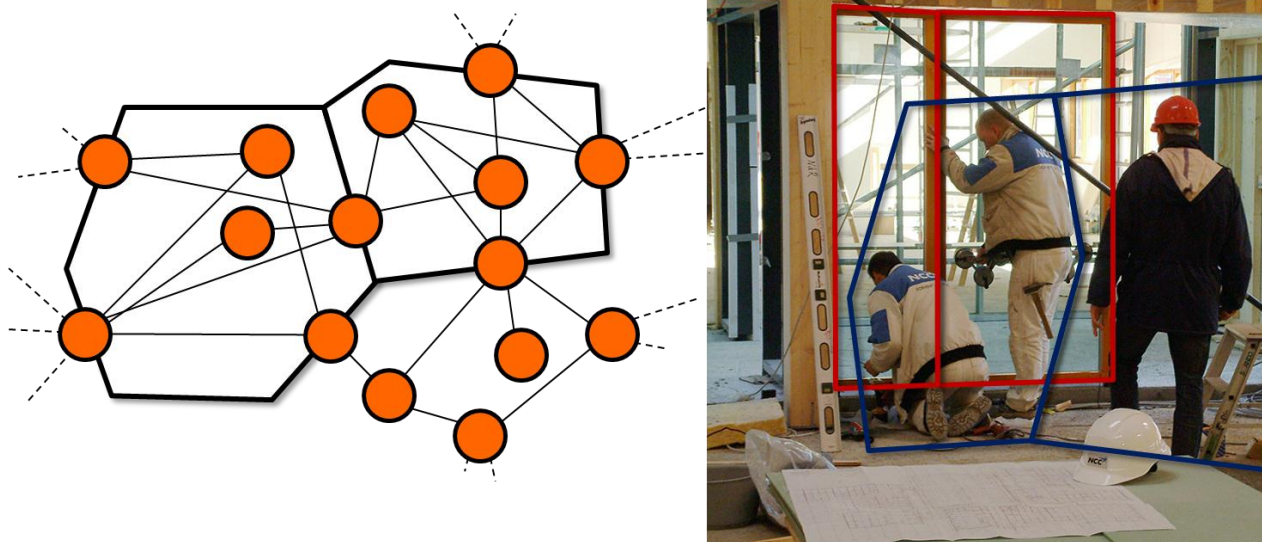
Modularity understood as elements or relations (Fixson 2003)

**FIGURE 3**

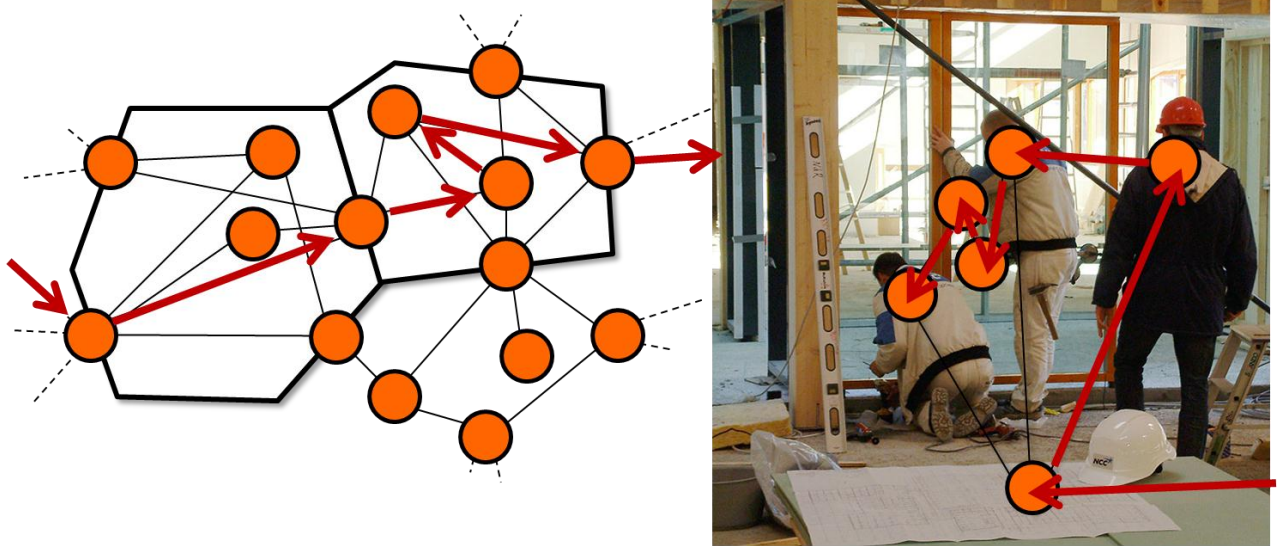
A network





**FIGURE 4****Actors in the network****FIGURE 5****Modules in an actor network**



**FIGURE 6****Processes in an actor network**

## TABLES

### TABLE 1

#### Characteristics of postmodern construction practices (Thuesen and Koch 2011)

Dimension	Characteristics
Technology	<p>Building materials: many different materials are in play although there has been a preference for concrete elements since the introduction in the 60's.</p> <p>Processes: Phase models, in-situ production, planning tools based on Critical Path Method (CPM), widespread but “islanded” use of information technology, project management as the predominant management philosophy.</p>
Industry	The organization of the industry is characterized by strong interest organizations representing many different professions like crafts, engineers, architects, contractors and material producers. The value chain is fragmented with an institutionalized separation of design and production.
Market and customers	The market is heterogeneous and characterized by fluctuation. The customers are addressed by the architects, who tailor unique projects specifically to the customers' individual needs.
Policy	The sector is regulated around competitive bidding, tendering systems, shared standards and general conditions for work and supply. The development of the regulation happens in close collaboration between the interest organizations and the governmental, but also increasing the EU.
Culture	The cultural organization of the industry is based on professions which are sustaining craft-differentiated education institutions with a strong element of apprenticeship learning processes. The building industry has over time developed a strong separation between design and production favouring the development of cultures around problem solving. The institutional learning processes in the past 30 years have been centred on the myth of the unique building, making the actors perceive the nature of the build process as complex or even chaotic. Finally, there is a strong focus on collaboration rhetorics among actors in the future development of the industry.
R&D	The organization and division of labour is mirrored and reproduced by the educational system. This system spans a wide range of cultural knowledge from tacit and embodied, situated in crafts to explicit and scientific in the academic professions. The central management practice is Project Management, which is inscribed in the educational system and influences the research agenda.

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